Space Weather Technical Forecast

Issued on Monday, 18 December 2023 at 12:28 Local

This technical forecast provides a four day assessment of space weather events. The probabilities stated below are for reaching or exceeding the given levels. For more information about space weather impacts please see the Met Office Space Weather Scales https://www.metoffice.gov.uk/weather/learn-about/space-weather/uk-scales

Space Weather Forecast Headline: Risk of G1 until midweek UTC. Risk of further R1 and S1 reducing.

Analysis of Space Weather Activity over past 24 hours

Solar Activity: Solar activity, as measured by GOES16 and 18 is Moderate with occasional C-class flares and a peak of M1.1, which was observed at 17/2017UTC from AR3514. This was the most active sunspot group of the previous week, having delivered the largest flare of solar cycle 25 so far in the form of an X2.8 on Thursday 14 December, however given its position on the extreme western edge of the disc, the sunspot group was no longer discernible to determine its classification.
Currently nine sunspot regions feature on the facing side, although these continue to be mostly small, stable and unipolar. The main exception to this was AR3519, which took the form of a Dso/Beta near centre-disc. This group saw the emergence of an intermediate penumbral spot that then migrated westwards to join the leader in the period, although this was not capped by significant flare activity.
A filament eruption was observed on the far northeast of the disc in El Teide H-Alpha at 17/1700UTC. Earth impacts are considered unlikely given its emission location. A further northeast quadrant event in the form of a possibly emissive C4.8 at 17/2132UTC from a new region. There were numerous other CMEs visible on coronagraph imagery, however these were considered to be far-sided or else limb events to no effect. No new Earth-directed CMEs were therefore in evidence.

Solar Wind / Geomagnetic Activity: Solar winds, as measured by DSCOVR at L1, was elevated to start the period with a decline to slightly elevated levels through the 24 hour period. Density was above average with a peak near 36ppcc at 18/0956UTC. The IMF was mostly moderate with a peak of 17nT at 17/1439UTC and a north-south component of +12/-15nT. The magnetic field showed significant variability and the phi angle was generally positive (away from the Sun). The net result of the above solar wind measures was for provisionally Quiet to Moderate Geomagnetic Storm G2 conditions, with Kp peaking at '6' in the 06-09UTC interval, while the Bz value was most strongly negative.

Energetic Particles / Solar Radiation: GOES16 high energy (greater than 10MeV) proton flux was on a declining trend near resting background levels, having been raised in response to the recent larger flares from AR3514. It was below the S1/Minor Radiation Storm threshold throughout the last 24 hours, with an early peak of 1.8pfu.
GOES16 high energy (greater than 2MeV) electron flux was mostly at Normal Background levels. The 24-hour fluence was well below the Active threshold (1e8 integrated pfu) on a mostly stable trend. The observation at 18/0001UTC was 1.35e6 integrated pfu.

Four-Day Space Weather Forecast Summary

Solar Activity: There remains a Chance of further Moderate activity and further active regions

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are likely over the eastern solar horizon into the new UTC working week. However these are probably not likely to adequately compensate for the loss of AR3514, and there has been a recent step-wise moderating risk of significant flares as a result.

Solar Wind / Geomagnetic Activity: There is now one further weak possible CME in the forecast, with arrival mooted for the very end of 19 or early on 20 December. The other component of the forecast, a persistent coronal hole, is more assured, and is due on 19 December. Geomagnetic activity carries a tail of risk of further G1 Minor Geomagnetic Storms through the remainder of day one, Monday 18 December, then probably falling to Quiet into early Tuesday. Later that UTC day, a coronal hole fast wind arrives and perhaps very late on the 15 December CME could arrive, with the effects of these perhaps combining to give a peak Chance of G1 before this again wanes through midweek to leave a Quiet end to the four-day forecast.

Energetic Particles / Solar Radiation: GOES16 high energy proton flux is now just very slightly above Background, with a Slight Chance of exceeding S1 again should AR3514 flare appropriately. This probability should then wane as this sunspot group progressively rotates from a potent position and further onto the far side.
High energy electron flux is likely to be stymied at GEO by the recent CME arrival, with a brief window then arising before further attenuation by CH82/+. The associated 24-hour electron fluence should therefore mostly remain near current levels, with any more appreciable rise probably delayed until after midweek UTC given a second inbound CME due into Wednesday.

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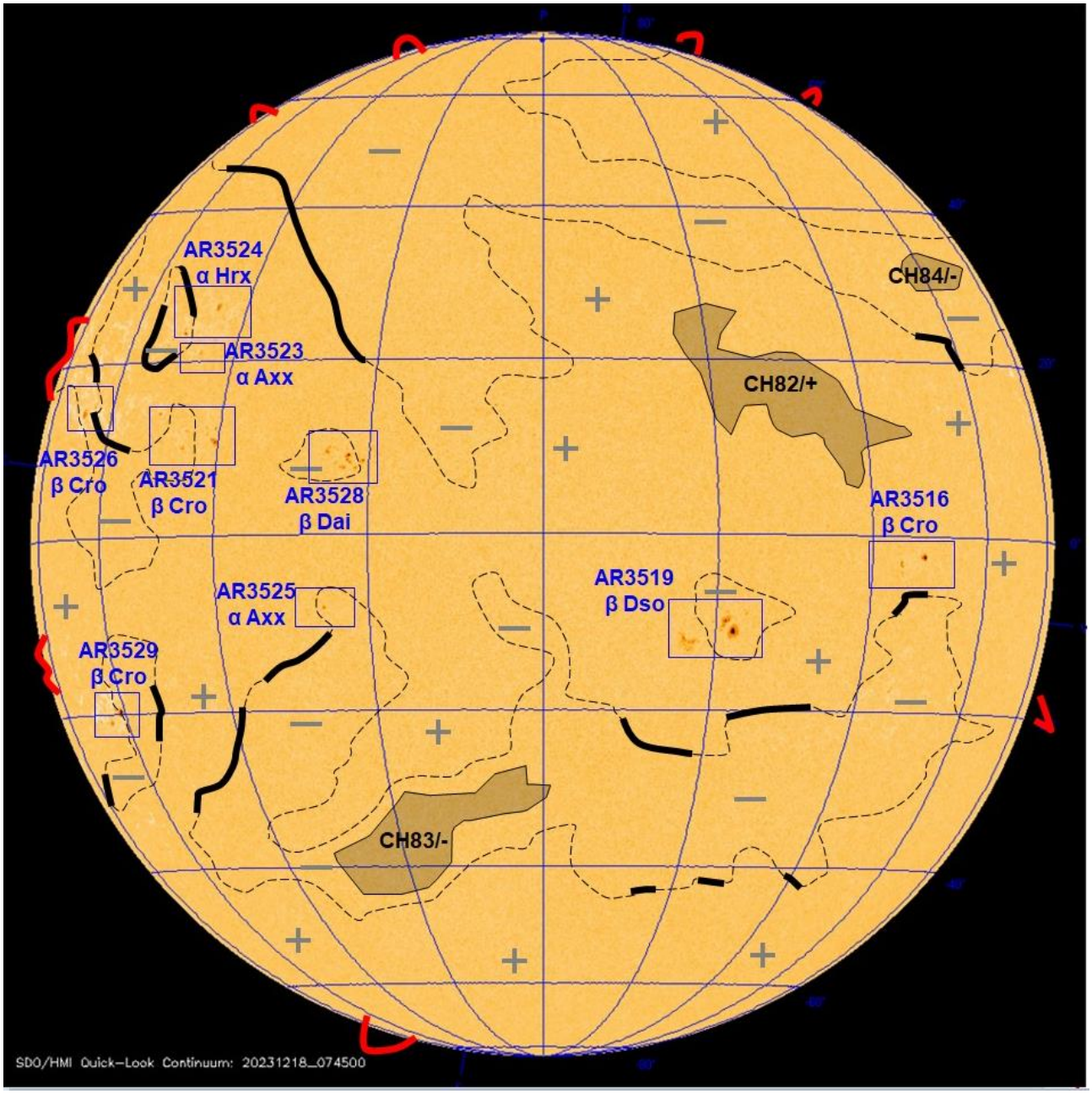
Figure 1. Solar Analysis Valid 0800UTC, Monday 18 December 2023.



Key: Filament ___ , Prominence ___ , Magnetic Field Line - - - , Polarity +/-, Coronal Holes: Grey shaded area CHxx +/-, Sunspot groups 25xx - Mt Wilson α-β-βγ-βγδ and Zurich-McIntosh Axx etc.

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Geomagnetic Storms:

There is now one possible CME in the forecast, from the 15/2100UTC south-centre disc filament eruption. This is low confidence for two reasons - firstly the analysis used scant, faint coronagraph imagery and was only tentatively linked to the event in question. Secondly, MOSWOC Enlil is currently thought to be low and late in bringing in CH82's fast wind - the model has this as arriving after this CME, but a 500km/s intervening fast wind is preferred, as per persistence. This will accelerate the CME and could lead to arrival as early as the very end of 19 December, although the bulk of any arising effects should still occur during the previously advertised 20 December. Although error-prone, given the CME's central position, Earth impacts are considered fairly likely but probably muted for being slow and weak.

The coronal hole-driven forecast now only comprises CH82/+, due 19 December. As stated, this coronal hole had a history of a westward pointing promontory that may produce a slightly earlier onset, although this now appears to have closed. Even though we are very near the minimally-geoeffective solstice, the intensity of the coronal hole and its history of having produced a G1 on last pass both lend themselves to a further chance of similar on 19 December.
All in, the first half of the UTC working week is likely to be relatively disturbed in terms of geomagnetism, with windows of more favourable conditions generally short-lived and of low confidence - probably most reliably present after the present CME effects have waned and before CH82, i.e. perhaps later Monday 18 and early Tuesday 19 December. There is a continuing Chance of G1/G2, largely the result of both the fast wind and perhaps an early arrival of the 15 December CME

Geo-Magnetic Storm Probability (Exceedance)	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Minor or Moderate	**G1 to G2**	Yes	40	40	20	5
Strong	**G3**	No	1	1	1	1
Severe	**G4**	No	1	1	1	1
Extreme	**G5**	No	1	1	1	1

Geomagnetic Activity - Earthbound Coronal Mass Ejections

Date/time 21.5R (UTC)	Halo: Full or Partial	Source	Source Location	Estimated Speed	Estimated Arrival Time	Comments
16/1947	Partial	Filament	S Centre	341 km/s	Very late 19 Dec or early 20 Dec	Onset time low confidence

Figure 2: Latest ENLIL model output with ensemble data, indicating probable insignificant CME impacts.

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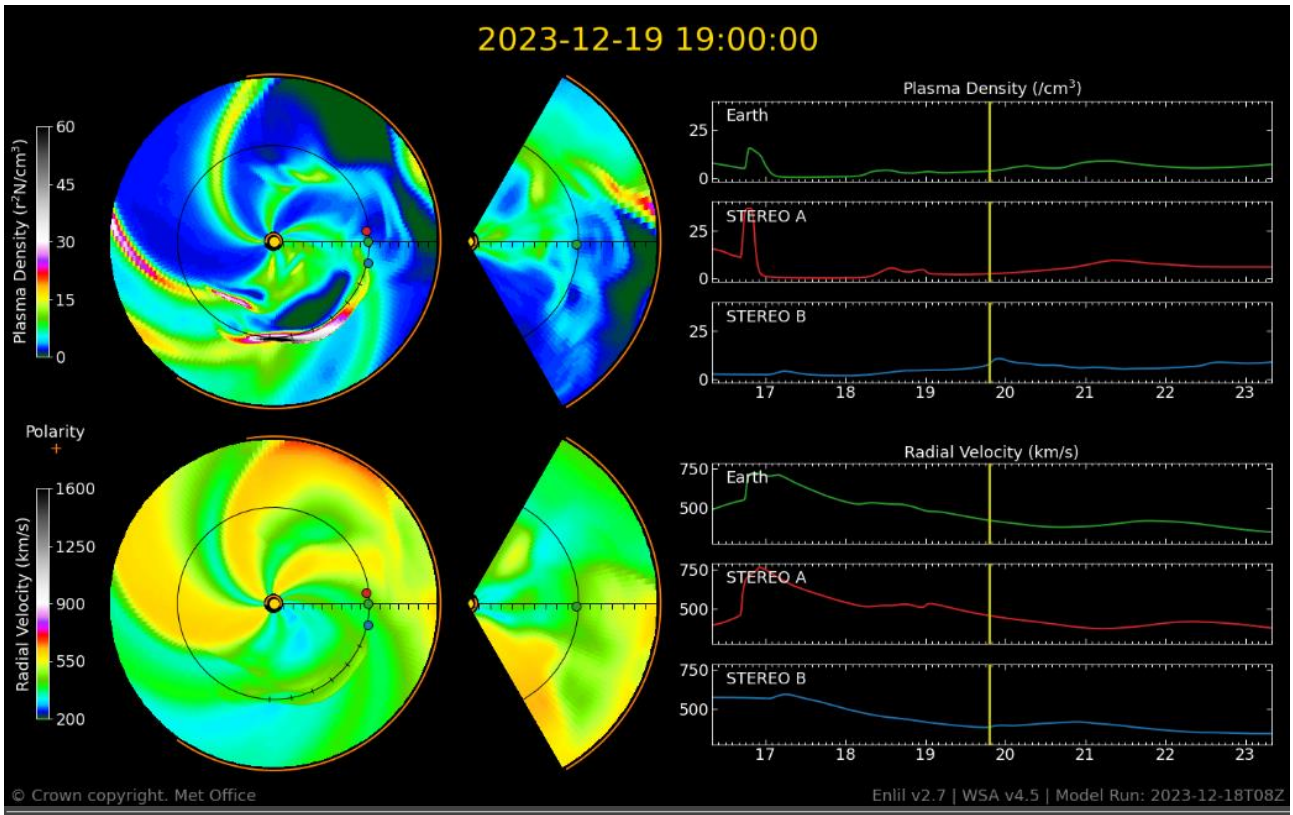

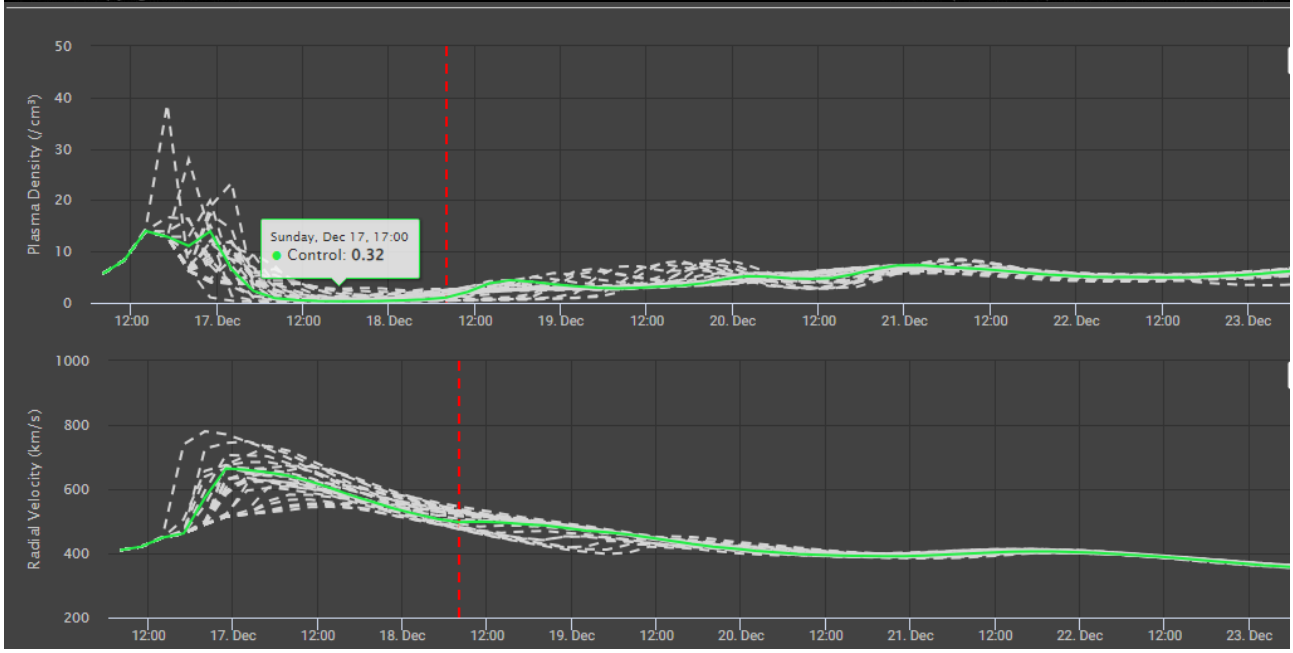

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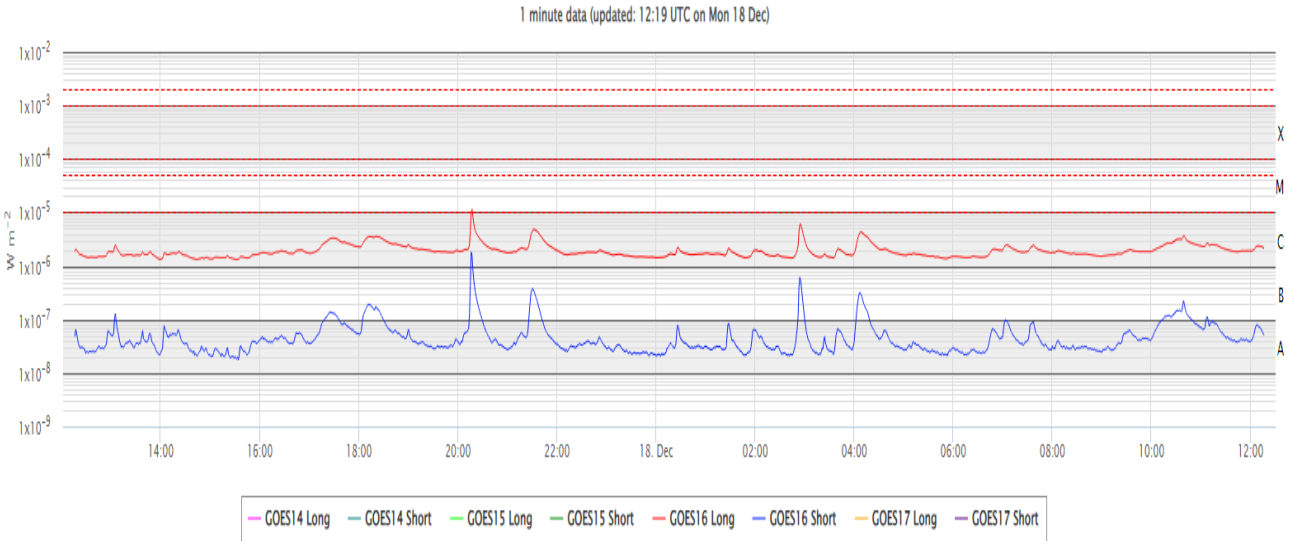
Radio Blackouts - X-Ray Flares:
There remains a daily Chance of isolated M-class flares. This follows a significant sunspot group (now rotated off the visible disc) that dominated X-ray activity of the past week - with a highlight being the largest X-ray flare since 2017 on 14 December in the form of the X2.8. The CME associated with this flare arrived in the past 24 hours to deliver G1/G2 intervals to Earth. The succeeding solar disc - while harbouring up to nine regions - pales by comparison to that of last week, with the vast majority of spotted regions appearing to be relatively simple, stable, magnetically unipolar affairs. There remain the returning Carrington locations of a few further sunspot regions over the eastern solar horizon in the period, however far-side soundings and limb EUV flux are not readily backed up by CME and dimming evidence to suggest anything comparable making up for the loss of Ex-AR3514.

X Ray Flares	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC)	Day 2 (00-24 UTC)	Day 3 (00-24 UTC)	Day 4 (00-24 UTC)
Probability			(%)	(%)	(%)	(%)
Active	R1-R2 M Class	Yes	30	30	20	20
Very Active	R3 to R5 X Class	No	5	5	1	1

Figure 3: Latest X-ray flux plot at GEO with several C-class flares over the past 24 days.



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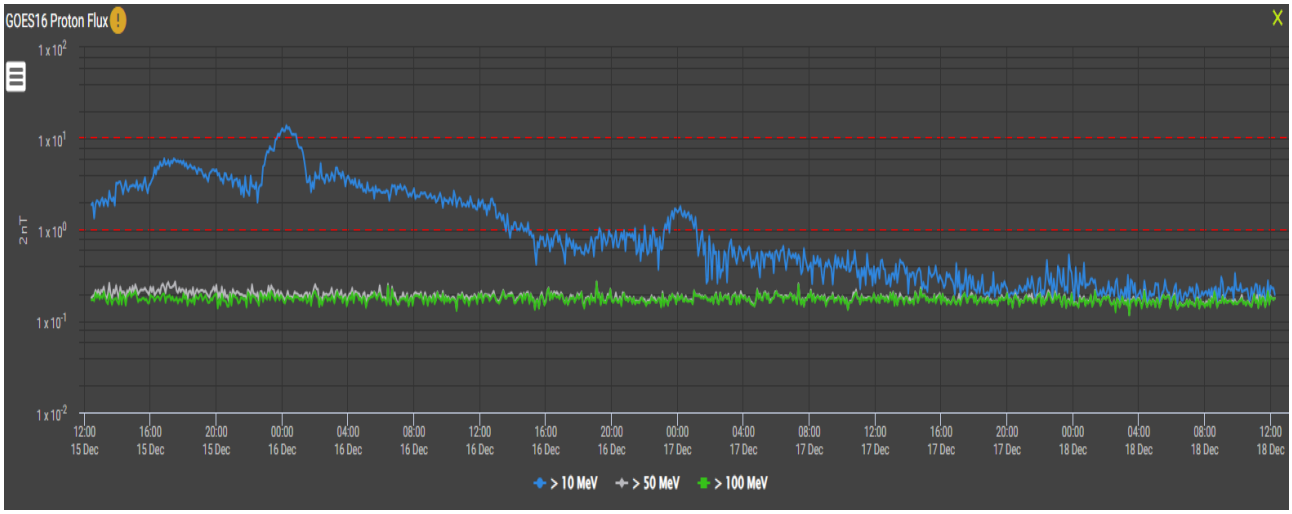
Solar Radiation Storms - (High Energy Protons):
The high energy (greater than 10MeV) proton flux observed by GOES16 has been on a downward trend after peaking at S1 late on 15 December in response to activity from AR3514. The observed spectra were relatively soft, with 50 and 100MeV protons unmoved, despite the westward emission location from the X and M-class flares. The breach of S1 was not seen at GOES18 in otherwise very similar spectra, perhaps implying a local effect for GOES16.

Flux levels are now very close to Background, and the risk of further breaches of S1 should now gradually reduce as AR3514 rotates further away from the west limb.

Radiation Storms Probability (Exceedance)	Level (cm^{-2} sr^{-1} s^{-1})	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Active	≥ S1	No	15	10	10	5
Very Active	≥ S3 *	No	1	1	1	1
* S3 ≥ 10 MeV ≥ 1000 pfu and / or ≥ 50 MeV ≥ 10 pfu. (pfu = $cm^{-2}sr^{-1}s^{-1}$)						

Figure 4: Latest Proton flux plot from past three days at GEO from GOES16 satellite with activity currently near background levels.



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High Energy Electrons Event (≥ 2MeV):
High energy electron flux is currently mostly at Normal Background levels, and is expected to remain so in the immediate term. The CME effects from Sunday 17 December are likely to have compressed the Van Allen belts however there is a window for recovery given the fast wind from CH82 arriving on Tuesday 19 December. This fast wind and a potential further CME into the 20 December are then likely to suppress levels at GEO once again for a time, but with the eventual easing probably allowing for the peak risk of Active fluence for the forecast as a whole - perhaps a Chance by later Thursday 21 December.

GEO Electron Environment Probability (Exceedance)	Level (cm^{-2} sr^{-1} day^{-1})	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Active	**≥ 2 MeV ≥ $1x10^8$**	No	1	20	5	40
Very Active	**≥ 2 MeV ≥ $1x10^9$**	No	1	1	1	1

Figure 5: High energy electron flux and REFM output, with little change in activity over past 24 hours.

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